

# A Method for Rapid Computation of Maximum Intensity Projection Images

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We describe a method for rapid calculation of maximum intensity projection (MIP) images. The method is applied to 10 example cases with more extensive testing in 1 case. Measurements of calculation time for all 10 cases show good performance (less than 1.2 seconds) for calculating a MIP image that is a very faithful representation of the original (less than 2% of pixels differ from original image). We also demonstrate that the computation time is related linearly to the number of pixels used, allowing arbitrarily rapid computation rates. This technique may be helpful as a navigation aid in evaluation magnetic resonance (MR) angiography data.

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**KEY WORDS:** image processing, magnetic resonance angiography, maximum intensity projection

MAGNETIC RESONANCE (MR) angiography produces images of vessels that are useful for evaluating many disease states, including aneurysms and atherosclerotic vascular disease. MR angiograms typically are displayed using the maximum intensity projection (MIP) technique, but such images are computationally intensive. This article describes a technique that significantly increases computation speed. The more rapid computation rate increases interactivity, which may increase the value of MR angiography.

## MATERIALS AND METHODS

By definition, only the brightest voxel along a projected ray of a few hundred voxels is seen in a MIP image; therefore MIP images of MR angiography data display less than 1% of the voxels present in the original data set. The technique described here represents the MR angiography data (source images) as a list of voxels sorted by intensity. This rearrangement allows the voxels of interest to be selected efficiently, which then can significantly reduce computation. The preprocessing step sorts all voxels by intensity and slice number, and stores the lists. Therefore, to find all voxels brighter than a certain intensity, one simply finds the position in the list that corresponds with this value. And if one proceeds through the list in the order of darkest to brightest, a test of prior values (for maximum brightness) is not required. The histogram also is stored, allowing easy computation of the number of voxels brighter than a specified value.

This technique was applied to 10 MR angiography data sets acquired for clinical purposes. Voxels brighter than 10% of the maximum pixel brightness were included in the sorted list (i.e.,

this was the starting index of the full list). For each data set and projection, the difference image (compared with standard MIP) was computed. The computation time for this method was measured and the number of voxels projected was recorded.

## RESULTS

Figure 1 demonstrates changes in computation speed and error as the number of voxels projected is increased. As expected, there is a nearly perfect linear relationship between the number of voxels used and the computation time. Table 1 gives that actual computation time per image for 10 example cases, using a visually reasonable number of voxels (i.e., essentially no perceptible degradation). The times ranged from 0.8 seconds to 1.2 seconds when executed on a Pentium 133-MHz (Intel, Santa Clara, CA) machine with 64 MB of RAM.

## DISCUSSION

This technique allows arbitrarily rapid computation of MIP images with the minimum possible loss in image quality on computers lacking special processors. Also, this technique allows for even more rapid computation in cases in which some loss in image quality is acceptable such as during interactive selection of the viewing angle.

Although faster rates will result in greater image degradation, these will be displayed so rapidly that image degradation may be difficult to perceive. Typically, such high computation rates are required when rapidly changing the viewing angle. Allowing easy navigation to the best viewing angle for subsequent computation of the highest quality image is an important feature. This technique may increase the diagnostic value of MR angiography by permitting easier navigation to the optimal viewing angle.

The disadvantages of this technique are the time required to perform the preprocessing step and the

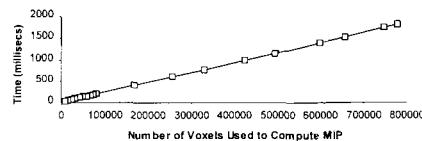
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*From the Department of Radiology, Mayo Foundation, Rochester, MN.*

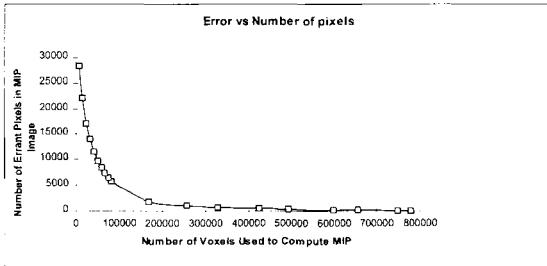
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(a)



(b)



**Fig 1.** Relationship between the computation time and the number of voxels used (A) and the percentage of pixels in the output image that were different from the standard (full fidelity) image versus the number of voxels used (B).

less efficient use of memory. The preprocessing step is not interactive and can begin as soon as the first MR angiography slice data becomes available. On a 133-MHz Pentium computer, the preprocessing step for a volume of  $256 \times 256 \times 100$  voxel requires approximately 3 minutes.

**Table 1. Calculation Times for the List-MIP Technique**

Case	Computation Time (ms)	% Errant Pixels
1	994	1.5
2	1024	1.3
3	1142	1.3
4	1195	1.2
5	908	1.4
6	839	1.3
7	1049	1.4
8	968	1.2
9	1163	1.5
10	848	1.3

Computation time was average time per image based on 10 images projected at 18-degree increments. Errant pixels is the percentage of pixels that differed between the standard method (full fidelity) and this method. All data sets were  $256 \times 256 \times 80$  or 100 slices.

## CONCLUSIONS

A method for rapid computation of MIP images from MR angiography data that significantly increases computation speed with little or no image degradation has been described. Furthermore, it is flexible enough to allow arbitrary image computation rates to be achieved with minimal loss of image quality. This method, however, incurs the penalty of a preprocessing step and less efficient storage of data.